International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249–6890; ISSN (E): 2249–8001
Vol. 9, Issue 6, Dec 2019, 463–474

DESIGN AND OPTIMIZATION OF AN ISOGRID COMPOSITE CYLINDER USING FEA

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ABSTRACT

The isogrid structure encompasses a thin outer skin that employs a repetitive equilateral triangular sample of stiffness ribs. This triangular grid sample behaves in a gross sense as an isotropic material and as a consequence given the isogrid identity by means of this project work, it is expected that isogrid structure of one-of-a-kind grid configurations can be analyzed and through conducting a parametric be trained and the geometry will also be optimizing.

In this paper, the isogrid cylinder by varying the three different materials (E-glass fibre, carbon fibre and aramid fibres) and different forces of the cylinder under uni-axial compressive loading. So, we are conducting the static and buckling analysis of the isogrid structure. Static and buckling analysis is to determine the stress, deformation and load Load Multiplier

3D modelling done by parametric software CATIA and analysis done in ANSYS.

KEYWORDS: Isogrid; FEA & Composite Materials

Received: Sep 20, 2019; **Accepted:** Oct 18, 2019; **Published:** Nov 05, 2019; **Paper Id.:** IJMPERDDEC201940

Original Article

INTRODUCTION

Matrix and grid structures are the shell like structures, which support the skin of any structure.

Kinds of Grid Structures: There are a few sorts of standard lattice structures, significant among them are as per the following:

- Grid structures with ribs running in four ways are alluded to as quadric-directional lattices.
- Grid structures with ribs that are in three ways are alluded to as tridirectional networks. An iso-lattice is a unique instance of a tridirectional matrix structure in which the ribs structure a variety of symmetrical triangles.
- Grid structures with ribs attracted just two directions are alluded to as point frameworks and in the event that the two headings are symmetrical, at that point this structure is alluded to as ortho-grid[1].

Use of Grid Structures: Grid structures are widely utilized in aviation, car and in common basic applications. The matrix structures comprise of characteristic protection from effect harm, delimitation and split engendering. Network structure conduct concentrate is inevitable, before usage. Since the aviation structures are exposed to joint stacking circumstances, an appropriate report must be done for the matrix structure model yet not under

single burden case; however, as a multidirectional surface in disappointment space, which is named as disappointment envelope[2].

LITERATURE REVIEW

Ideal Design of Grid Cylindrical Structures Using Homogenized Model[3] another homogenisation approach was connected for the examination of composite isogrid structures. This methodology permits to make the improvement of the isogrid structures quicker. The numerical model has been confirmed by methods for the near examination for the homogenized model and accurate FEM model. Consequences of the investigation are introduced and talked about. Ideal Structural Design of CFRP ISOGRID Cylindrical Shells[4] with a decent understanding between clasping examinations by FEM and unit hub pressure tests for the CFRP ISO network round and hollow shells. This paper depicts an ideal plan of CFRP isogrid barrel-shaped shell. At the point when the CFRP ISO network round and hollow shell gets a recommended uni-pivotal compressive burden, the article is to limit the heaviness of the CFRP isogrid tube shaped shell exposed to limitation states of no disappointment and no clasping by utilizing the hereditary calculation (GA) strategy. In the GA procedure, the clasping and CFRP disappointment burdens were gotten by an approximated capacity planned with the moving least square (MLS) strategy for sparing computational assets. Plan and Fe Analysis of Composite Grid Structure for Skin Stiffening Applications[5]: Matrix structures are the shell-like structures, which supports the skin of any structure. At the point, grid structures when made up with composite materials find generally excellent application in aviation field. The properties of the skin can be consistently circulated, thickness of the skin can be decreased which under study diminishes the all-out weight of the structure. The present skin-hardened structures are having tough skin and it is contributing more weight, and it is taking some piece of the heap. By utilizing lattice structures, we can diminish the skin thickness and burden shared by the skin can be limited which gives the harm tolerant plan idea for aviation structures, and it additionally establishes framework for the modern versatile structures. In this manner, by and by composite matrix structure investigation is directed to know the viability of the different lattice structures in skin hardening applications.

OBJECTIVE

In the present work, isogrid ideas will be utilized for skin hardening applications. In the initial step of our task, a rectangular board or plate is structured with isogrid skin stiffener for some ideal burden conditions with same skin thickness at various materials. The structured plates are dissected for diversion and stress utilizing limited component investigation (FEA) programming, for example, ANSYS.

PROBLEM STATEMENT

To evaluate the best performance of the isogrid cylinder with three different materials (E-glass fibre, armed fibre and carbon fibre) with same configuration.

MODELING

The following dimensions15 are used to design 3D model by defining a set of key points in which points define the geometry of the structure. These were joined by lines. Areas were created by using these lines.

Cylinder Dimensions:

Diameter = 63.54 cm.

Height = 36.40 cm.

Rib breadth (b) = 1.45 cm.

Rib thickness (t) = 0.17 cm.

Cylinder thickness = varies accordingly.

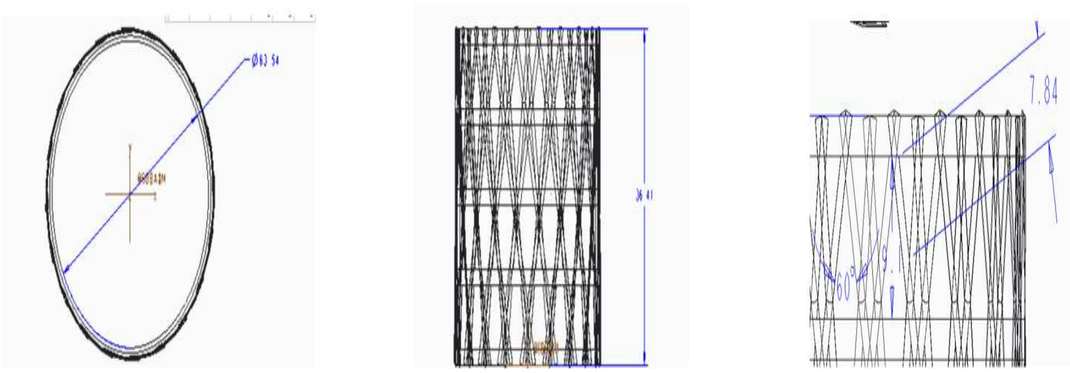


Figure 1

Meshing and Boundary Conditions

Using solid tetra four-node element mesh is developed. Later, boundaries are assigned where load is applied from top and bottom of the cylinder is rested on the ground.

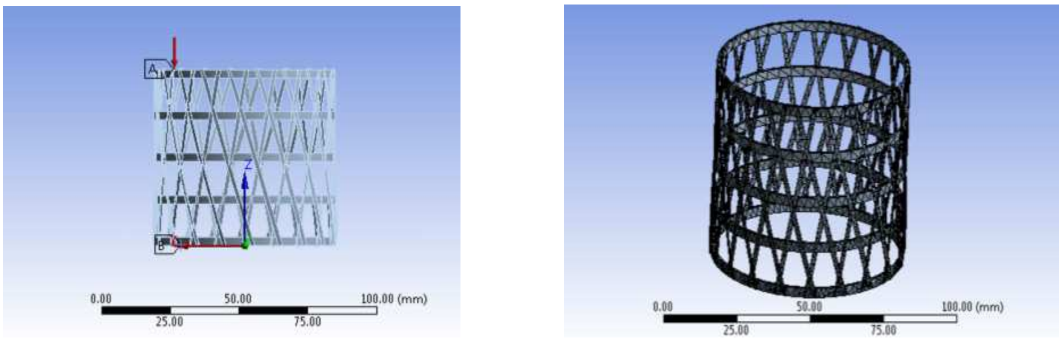


Figure 2

Material Properties

All these material properties are taken from MMPDS, which are defined.

Property	Value	Unit
Density	2620	kg m^-3
Isotropic Secant Coefficient of Thermal Expansion		
Isotropic Elasticity		
Derive from	Young's M...	
Young's Modulus	72000	MPa
Poisson's Ratio	0.21	

Property	Value	Unit
Density	1800	kg m^-3
Isotropic Secant Coefficient of Thermal Expansion		
Isotropic Elasticity		
Derive from	Young's M...	
Young's Modulus	70000	MPa
Poisson's Ratio	0.23	

Density	1440	kg m^-3
Isotropic Secant Coefficient of Thermal Expansion		
Isotropic Elasticity		
Derive from	Young's M...	
Young's Modulus	82000	MPa
Poisson's Ratio	0.35	

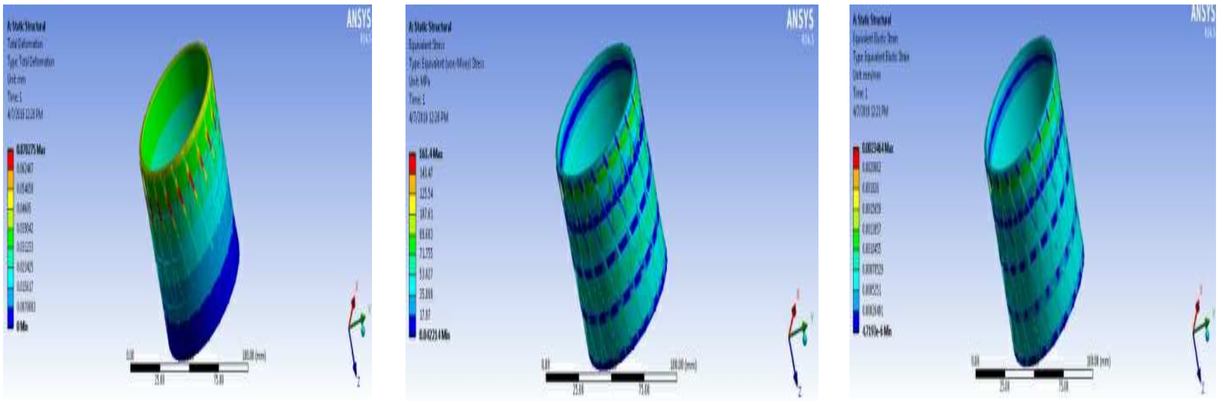
Figure 3

The material properties were added according to the required specifications according to their required quantity. All the three materials were choosen, such as E-glass fiber, carbon material and aramid material.

RESULTS AND PLOTS

In static analysis, we observe Glass epoxy is best with stand load capacity compared to carbon fibre and armed fibre, but when it comes to deformation, carbon fibre shows high strength of deformation.

E-Glass Fiber



Deformation. **Stress.** **Strain.**

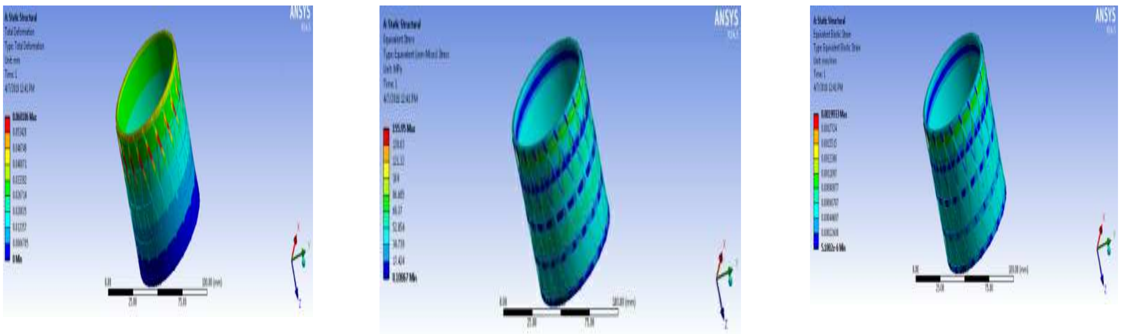
Figure 3: E-Glass Fiber

According to the E-glass fiber, the maximum deformation at free end of the isogrid structure because of the fix to the one end of the isogrid. The maximum deformation is 0.020275 mm and the minimum deformation is 0.001003 mm.

As per E-glass fiber, the maximum stress at fixed end of the iso grid structure because of the fix on the one end of the iso grid. The maximum stress 161.4N/ mm^2 and minimum deformation is 0.042N/mm^2.

As result of E-glass fiber, the maximum strain at fixed end of the iso grid structure because of fix to the one end of the iso grid. The maximum strain is 0.002346 and minimum deformation is 0.000026491N/mm^2.

Aramid Fiber



Deformation. **Stress.** **Strain.**

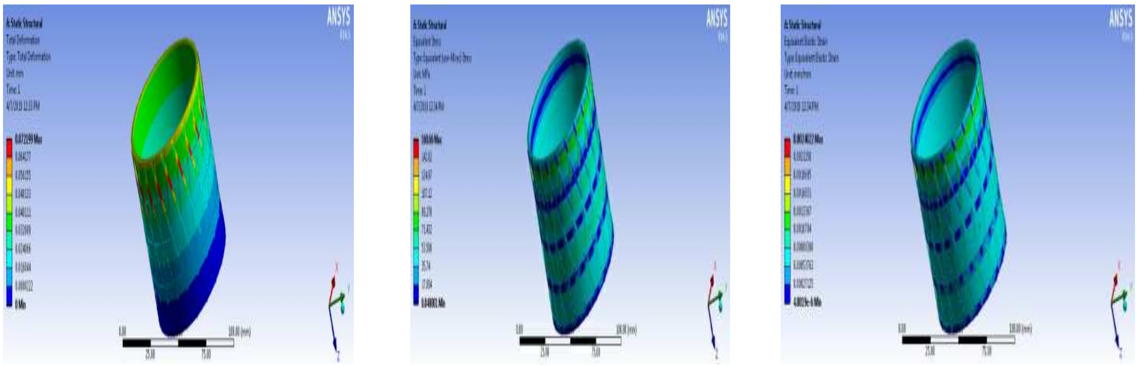
Figure 4: Aramid Fiber

- According to the aramid fiber, the maximum deformation at free end of the isogrid structure because of the fix to the one end of the isogrid, the maximum deformation is 0.60106 mm and the minimum deformation is 0.0066785 mm.

- As per aramid fiber, the maximum stress at fixed end of the isogrid structure because of the fix to the one end of the isogrid. The maximum stress 155.05N/mm^2 and minimum deformation is 0.10867N/mm^2.

- As result of Aramid fiber, the maximum strain at fixed end of the isogrid structure because of fix to the one end of the isogrid, the maximum strain is 0.0019933 and minimum deformation is 0.000026491N/mm^2.

Carbon Fiber



Deformation. **Stress.** **Strain.**

Figure 5: Carbon Fiber

- According to the carbon fiber, the maximum deformation is at free end of the isogrid structure because of the fix to the one end of the isogrid. The maximum deformation is 0.072199 mm and the minimum deformation is 0.0080222 mm.

- As per carbon fiber, the maximum stress at fixed end of the isogrid structure because of the fix to the one end of the isogrid. The maximum stress 160.66N/mm^2 and minimum deformation is 17.894 N/mm^2.

- As a result of the aramid fiber, the maximum strain at the fixed end of the isogrid structure because of the fix to the one end of the isogrid. The maximum strain is 0.0024022 and minimum deformation is 0.00027172N/mm^2.

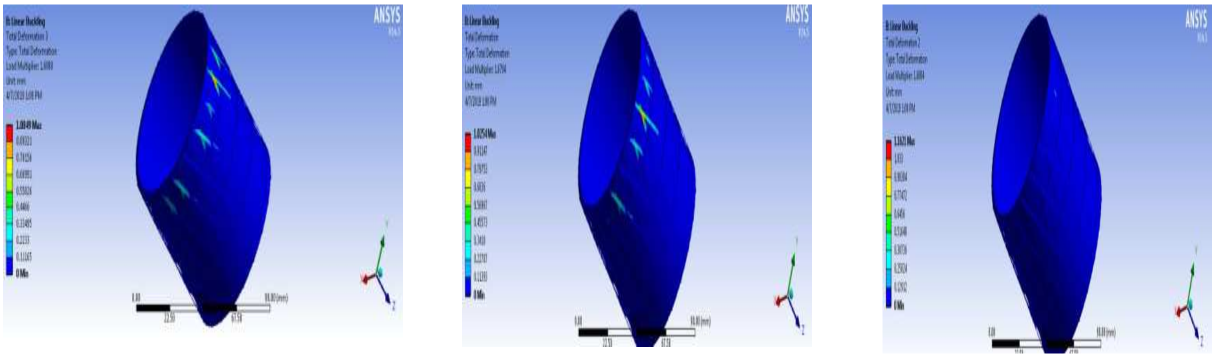
STATIC ANALYSIS

Table 1: Static Analysis

Material	Load (Mpa)	Deformation (mm)	Stress (N/mm^2)	Strain
E-Glass Fiber	250	0.07025	161.4	0.0023464
	500	0.14055	322.79	0.0046929
	750	0.21082	484.19	0.0070339
Carbon Fiber	250	0.72199	160.66	0.0024022
	500	0.1444	321.32	0.0048044
	750	0.2166	481.98	0.0072066
Aramid Fiber	250	0.060106	155.95	0.0019933
	500	0.12021	311.89	0.0039865
	750	0.18032	467.84	0.0059798

Here, we observe aramid fiber has the highest with standable strength to buckle, whereas E-glass fiber buckles faster. According to the following results, buckling is happening at the place of load applied.

Aramid Fiber



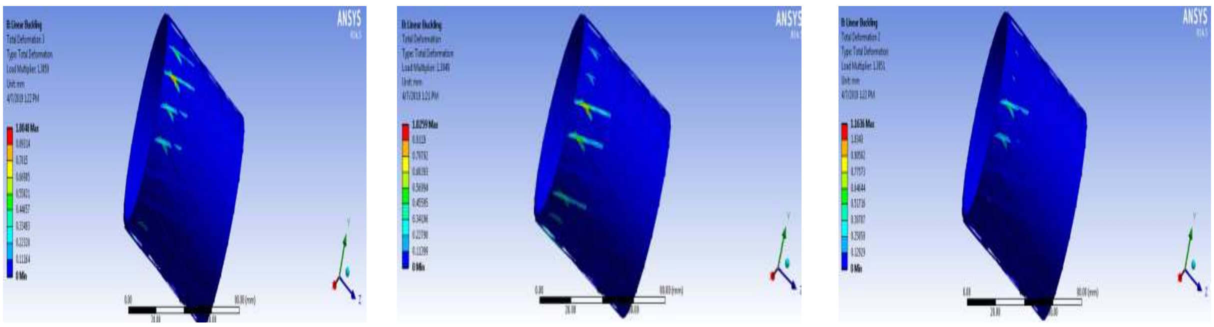
Total Deformation 1. **Total Deformation 2.** **Total Deformation 3.**

Figure 6: Aramid Fiber.

The buckling analysis of isogrid structure of an aramid fiber material with three different types of total deformation was applied and load multiplier was added according to it.

- Total deformation -1 was 1.0254, whereas after adding of load multiplier 1.6794.
- Total deformation -2 was 1.1621, whereas after adding of load multiplier 1.804.
- Total deformation -3 was 1.0049, whereas after adding of load multiplier 1.6808.

Carbon Fiber



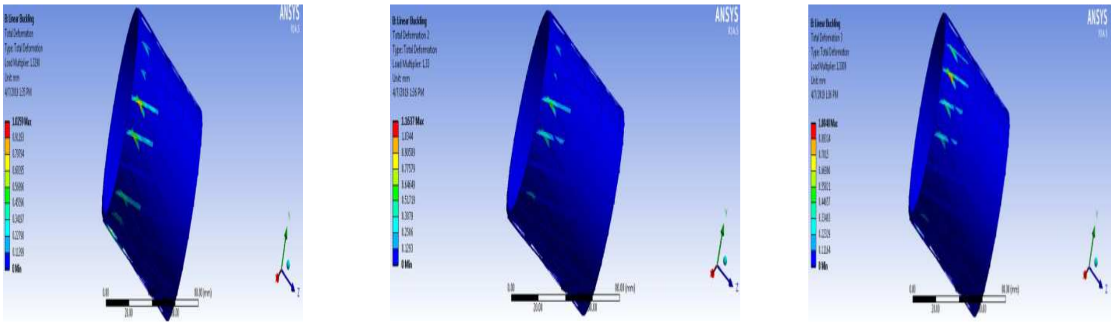
Total Deformation 1. **Total Deformation 2.** **Total Deformation 3.**

Figure 7: Carbon Fiber.

The buckling analysis of isogrid structure of a carbon fiber material with three different types of total deformation was applied and load multiplier was added according to it.

- Total deformation -1 was 1.259, whereas after adding of load multiplier 1.3049.
- Total deformation -2 was 1.1636, whereas after adding of load multiplier 1.3051.
- Total deformation -3 was 1.0048, whereas after adding of load multiplier 1.3059.

E-Glass Fiber



Total Deformation 1. **Total Deformation 2.** **Total Deformation 3.**

Figure 8: E-Glass Fiber.

The buckling analysis of isogrid structure of an E-Glass fiber material with three different types of total deformation was applied and load multiplier was added according to it.

- Total deformation -1 was 1.0249, whereas after adding of load multiplier 1.3298.
- Total deformation -2 was 1.1637, whereas after adding of load multiplier 1.331.
- Total deformation -3 was 1.0046, whereas after adding of load multiplier 1.3309.

Buckling Analysis

Table 2: Buckling Analysis

Material	Total Deformation(mm)	Load Multiplier
E-Glass Fiber	1.0249	1.3298
	1.1637	1.331
	1.0046	1.3309
Carbon Fiber	1.259	1.3049
	1.1636	1.3051
	1.0048	1.3059
Aramid Fiber	1.0254	1.6794
	1.1621	1.6804
	1.0049	1.6808

The buckling analysis of all the three fiber materials such as E-glass fiber, carbon fiber and aramid fiber were done, whereas total deformation took place, load carried accordingly and the load was load multiplied according to their applied ranges.

CONCLUSIONS

In this study, we analysed the isogrid cylinder with different materials. By observing the static analysis results, the stress is less at carbon fiber when compared to the other two materials.

When coming to buckling loads, aramid fiber gave best results to withstand the structure. The following graphs show the difference between three materials for various conditions during static loads.

So, we can conclude that composite materials are suitable for isogrid structure.

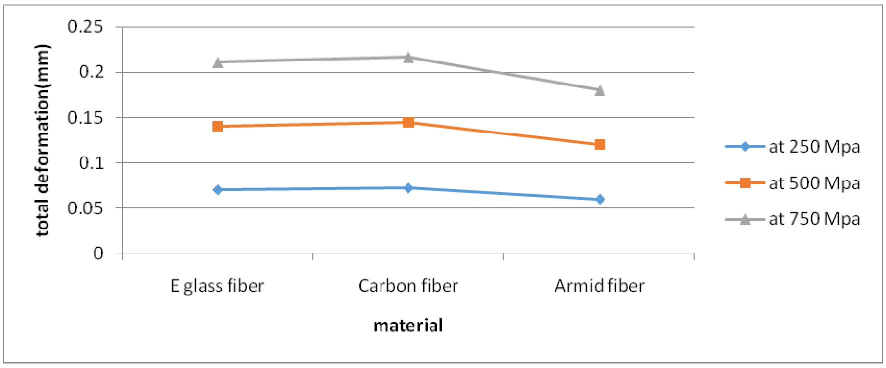


Figure 9

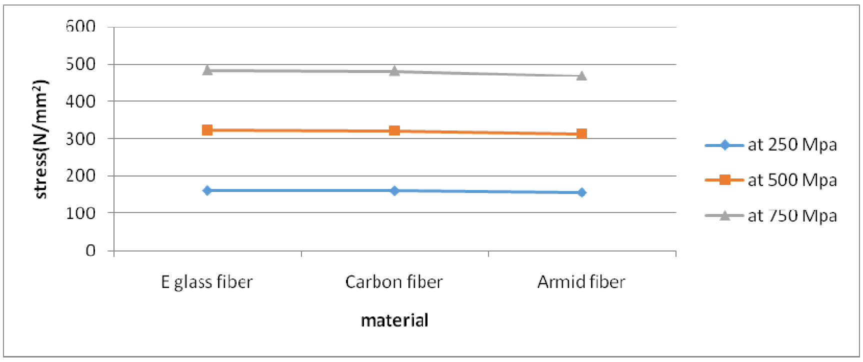


Figure 10

FUTURE SCOPE

Several recommendations are made for improvements and further analysis on the design and analysis tool.

Geometry

- To improve the geometry, influence cuts on the running loads should be taken into account as well as the evaluation method should be changed for these expectations.
- More geometry options should be added to the model, such as changing the position of the aerodynamic center of tail after the tail center of gravity.

Evaluation

- The metal buckling analysis could be extended for the tension/shear effect on buckling. Now, only compression/shear buckling effect is taken into account.
- The composite evaluation methods should be checked and extended, such as crack analysis of composite.
- The model could be extended to evaluate other upcoming materials, like fiber metal laminates.
- A raw material analysis and material cost analysis for metal could be added to the tool in order to give a first impression about the needed amount of material and its cost.

Optimization

- A better and faster optimization method should be implemented in the model to give faster results.

- The optimization could be done for more criteria, such as stringer spacing and stringer area.

Validation

- The validation of the running loads of model could be done by an FEM model, in order to proof the analytical model.

Tool

- An input file can be created for the parameters and option selections. This makes it much easier to change aircraft specifications and load cases.
- The creation of charts can be automated by implementing the creation of chart in the tool code, which will save time afterwards by analyzing the results.

Other

- A composite cost study should be performed. This study must identify difference in cost between composite fuselage and an aluminium fuselage. A break-even point, a minimum amount of saved weight can then be established, beyond which it is cheaper to produce a composite fuselage.

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